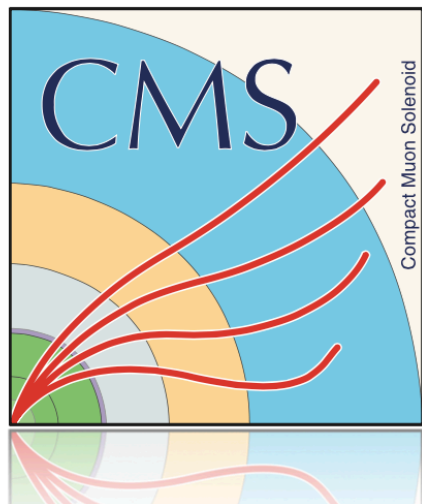
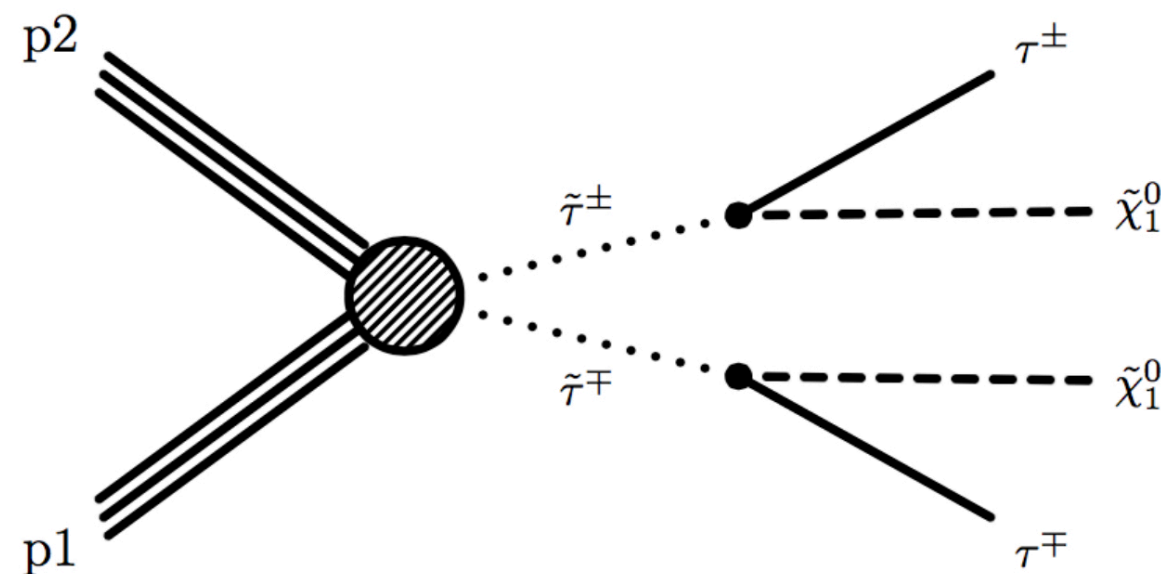


Current and future searches for direct tau slepton production in the all-hadronic final state at CMS

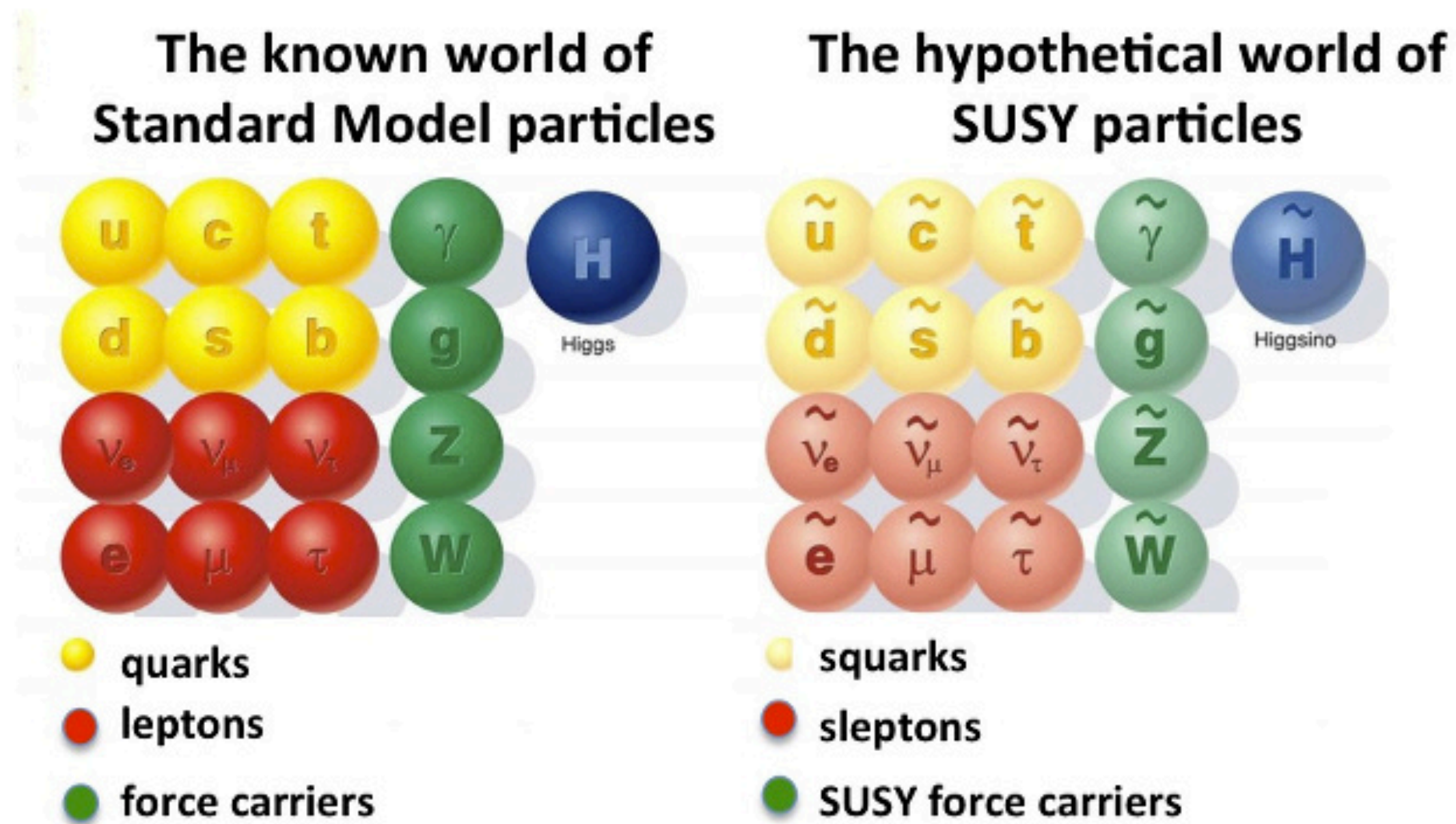


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Oct. 26, 2018



Supersymmetry Pheno



Supersymmetry (SUSY) introduces a space-time symmetry between bosons and fermions, results in a whole zoo of new particles

- *An elegant theory capable of solving some of the most glaring flaws in the standard model.*

Current Status of SUSY

1. For stable Higgs at 125 GeV the SM needs fine tuning at $O(30)$ decimal places
 - New Physics, i.e. SUSY, can protect the Higgs mass against these radiative corrections
2. Cosmological abundance of dark matter may imply undiscovered particles
 - Lightest SUSY particle (LSP, $\tilde{\chi}_1^0$) is an excellent candidate

These two theoretical arguments make a compelling case for SUSY

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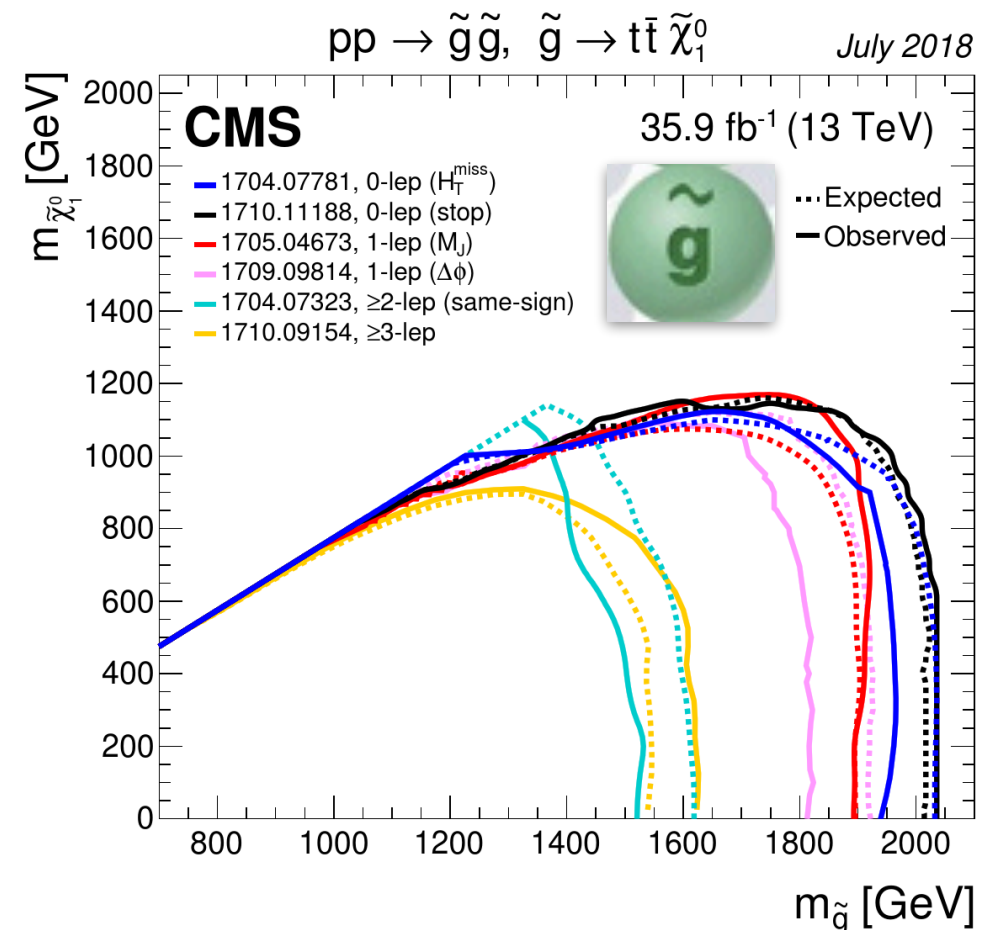
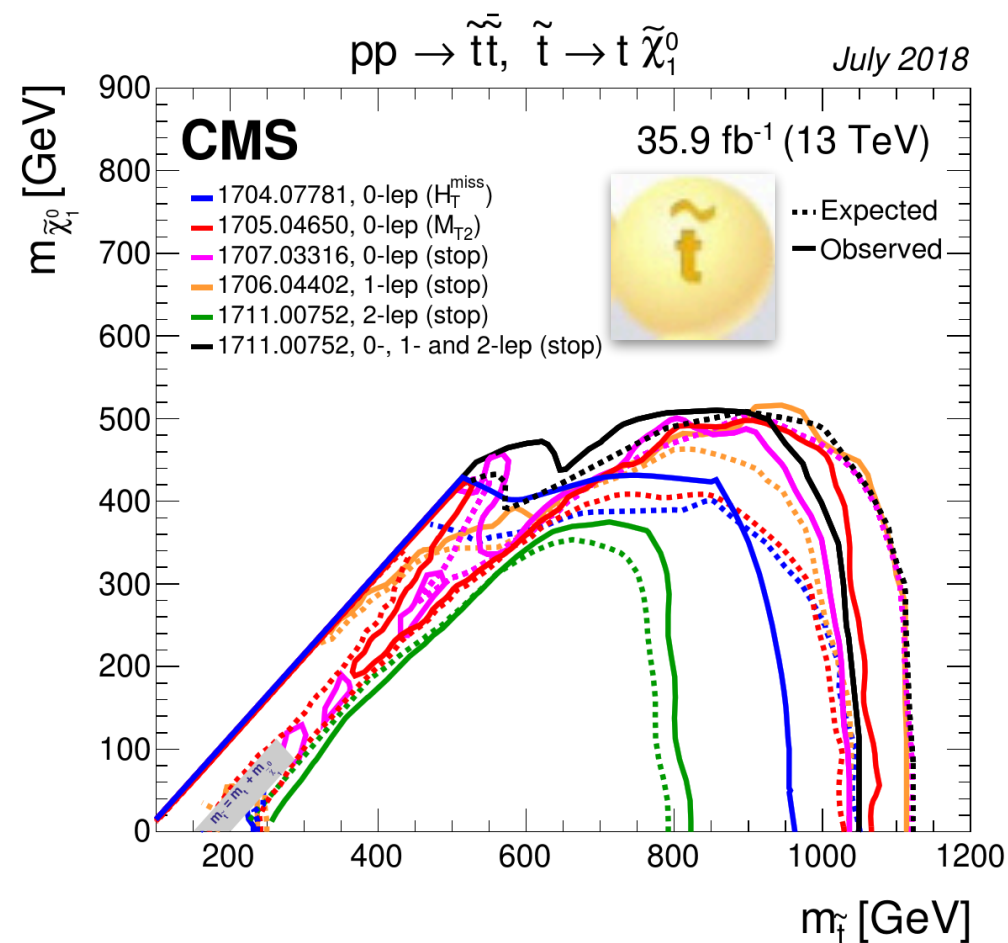
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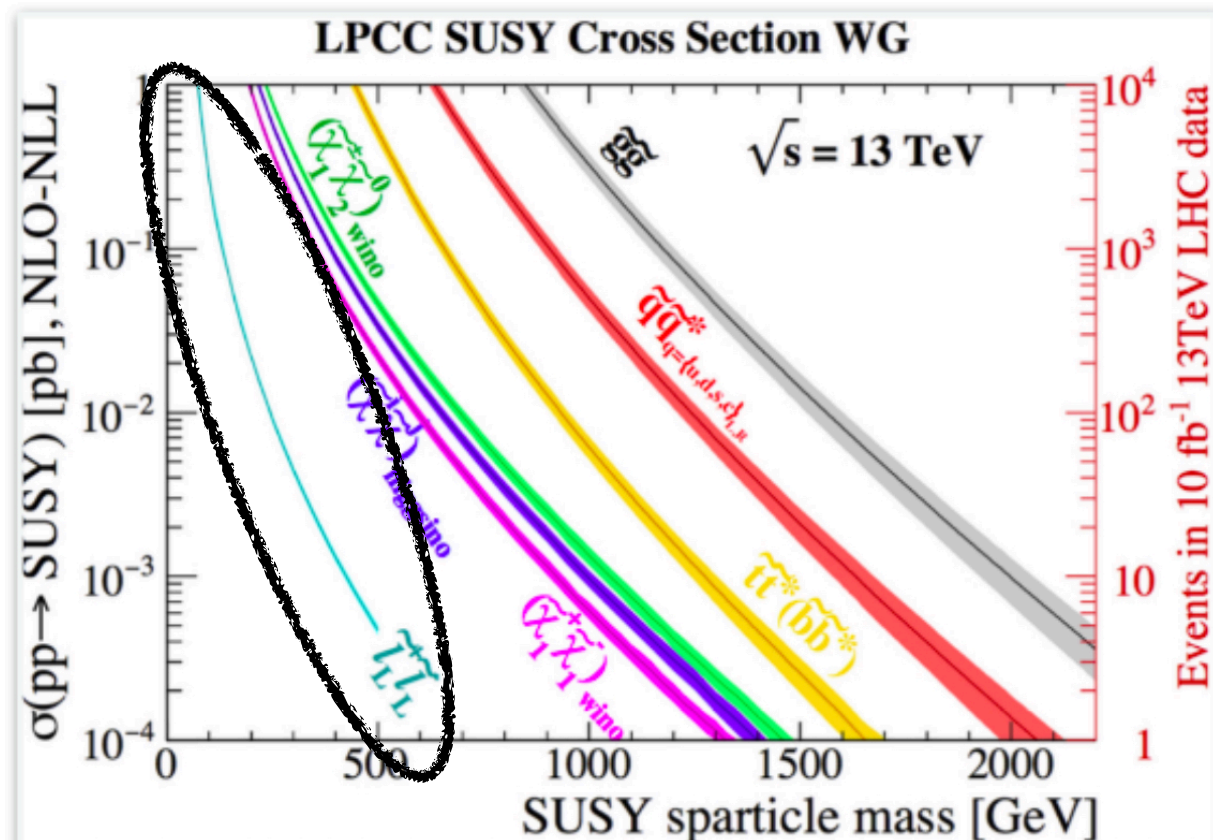


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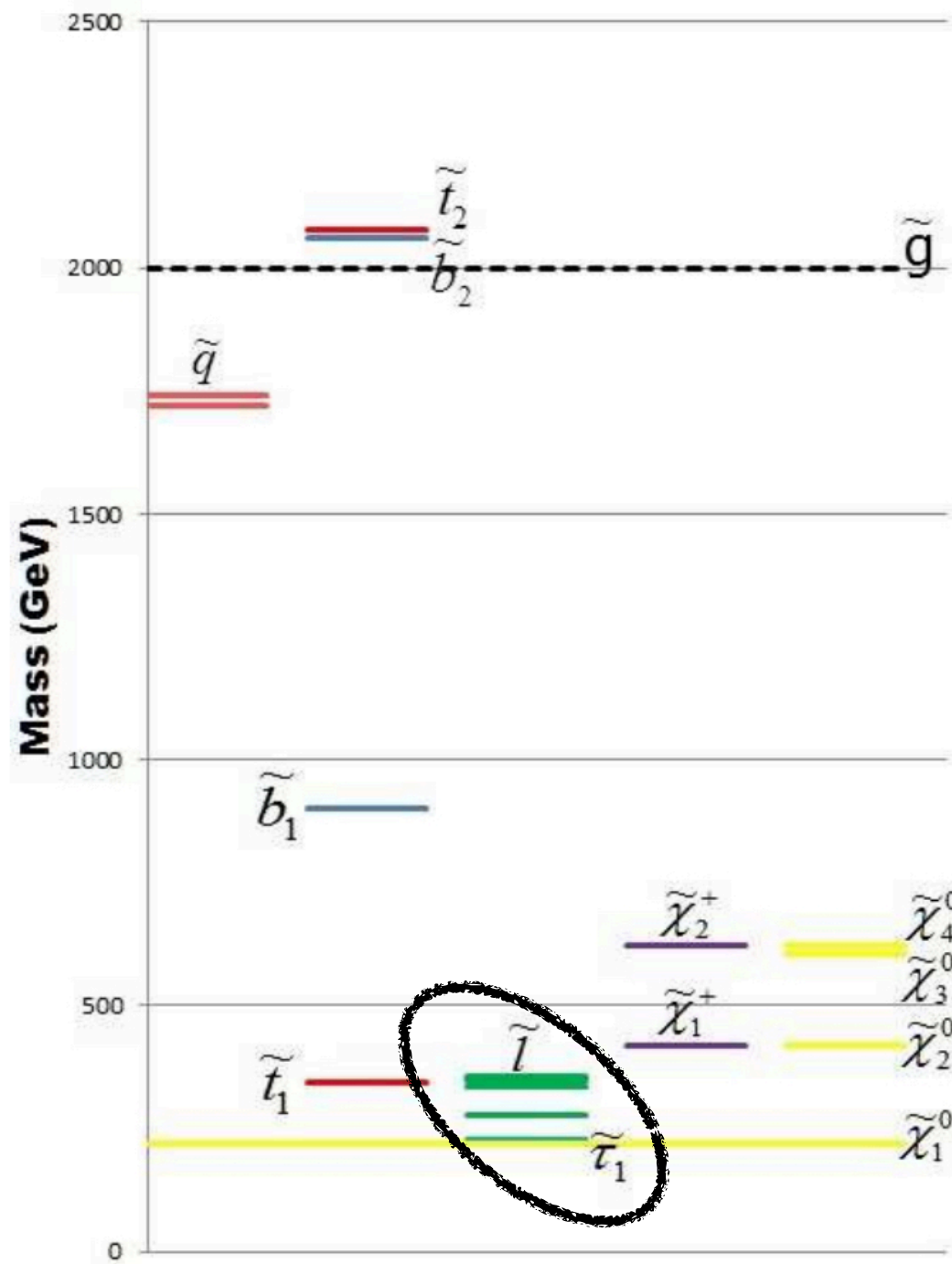
Due to small cross-section, direct slepton production remains **largely unexplored at the LHC**

- SUSY could very well be hiding here, we must check!

Current Status of SUSY

One loop effects of natural SUSY in indirect searches for SUSY particles at the ILC

<https://arxiv.org/abs/1703.07671>



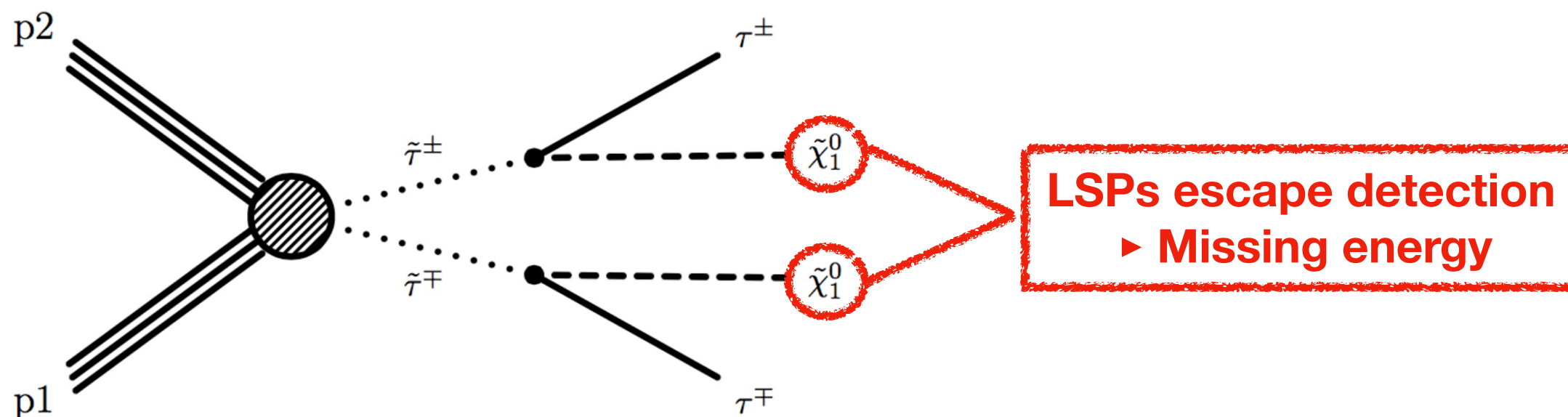
Due to small cross-section, direct slepton production remains **largely unexplored at the LHC**

- SUSY could very well be hiding here, we must check!
- In some specific SUSY models the stau could be the first discoverable SUSY particle at the LHC

Searching for Staus at the LHC

All-hadronic Analysis Baseline Selection :

- Two opposite sign reconstructed hadronic taus



Searching for Direct Stau Production :

- Missing transverse momentum (MET) and its associated mass scale variables are used to isolate signal
 - * ΣM_T = Sum of the pair-wise transverse mass between the MET and reco taus
 - * M_{T2} = Min. of max. pair-wise transverse mass between a pair of hypothetical missing particles (that reconstruct the MET) and the two detected taus

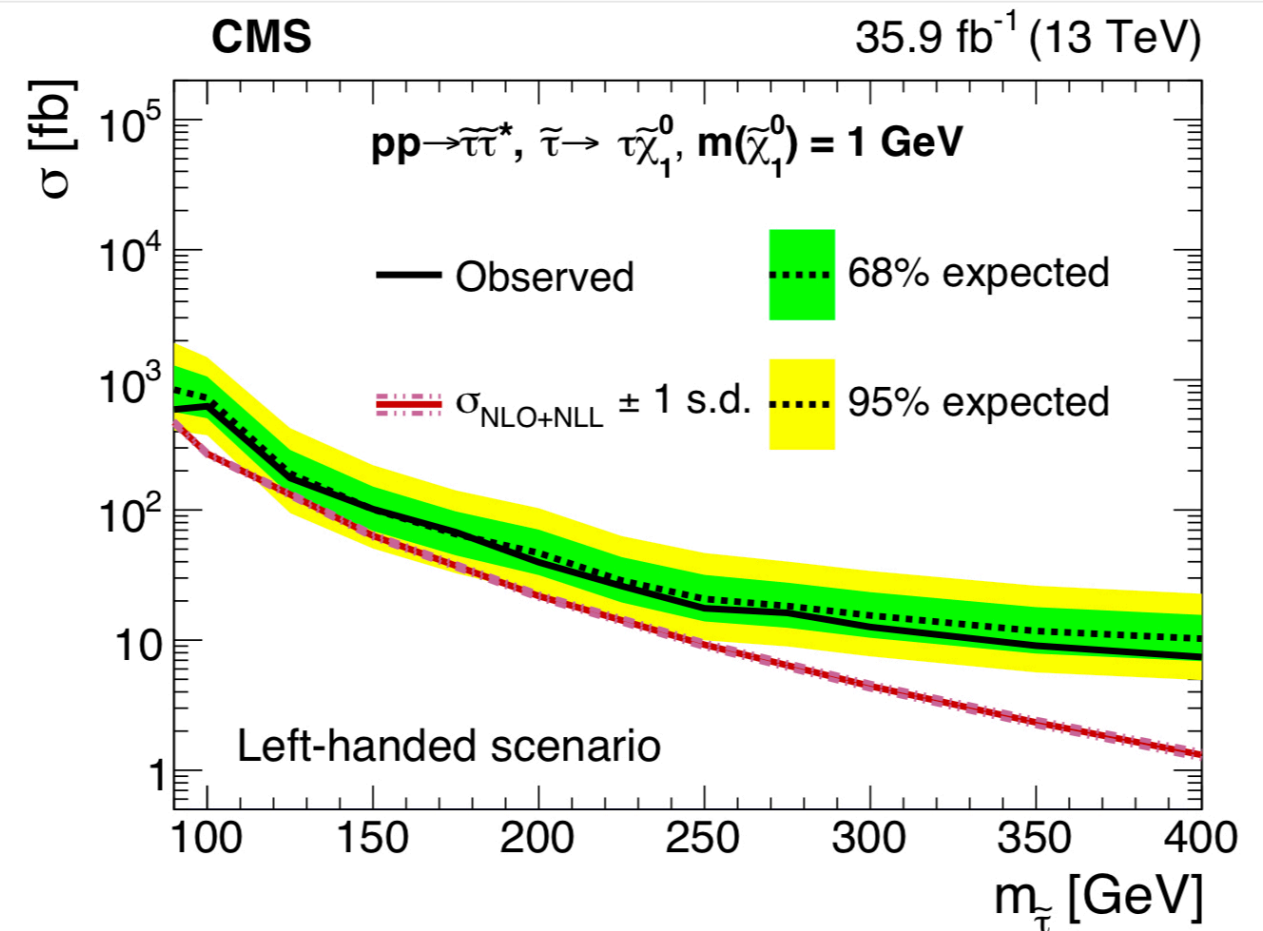
Searching for Staus at the LHC

2016 analysis accepted for publication in JHEP

- [<https://arxiv.org/abs/1807.02048>]
- No significant excesses are observed

Analysis not yet sensitive enough to exclude stau production scenario

- More data and improved analysis tech. needed to boost sensitivity



Latest Object Improvements

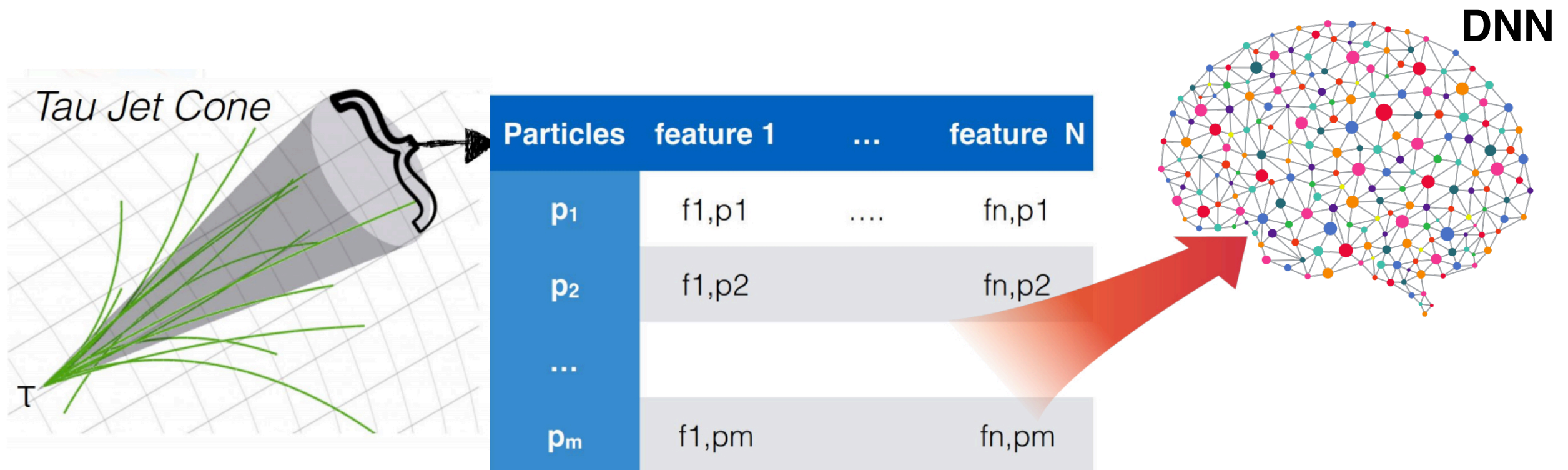
Developed “DeepPF tau isolation” a new approach to discriminating genuine isolated taus from fake objects (hadronic jets, muons, etc.)

1. Start from raw detector output
2. Reconstruct “Particle Flow” particles (e , γ , π^+ ,...)
3. Variables from particles contained in cone centered on the tau are formatted into a 2-D table & fed into a Deep Neural Network (DNN)

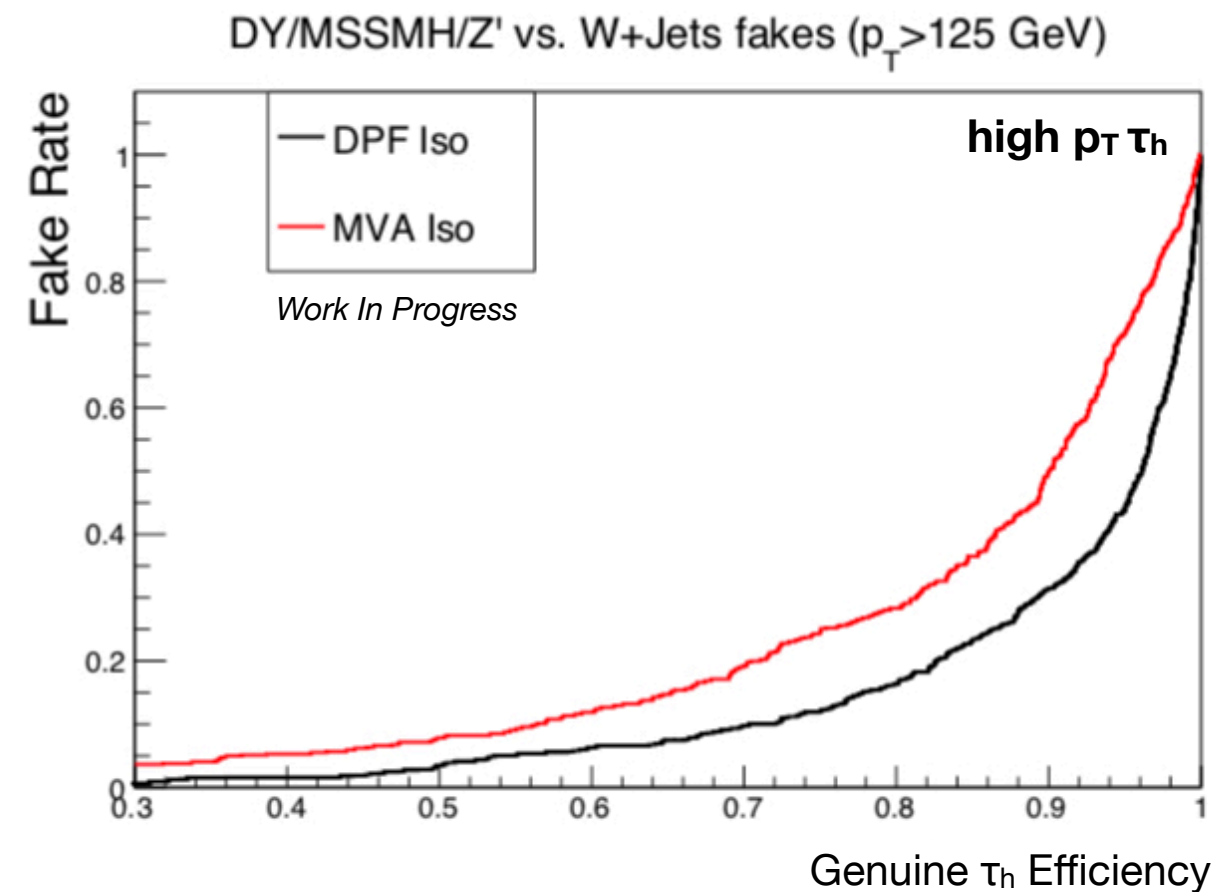
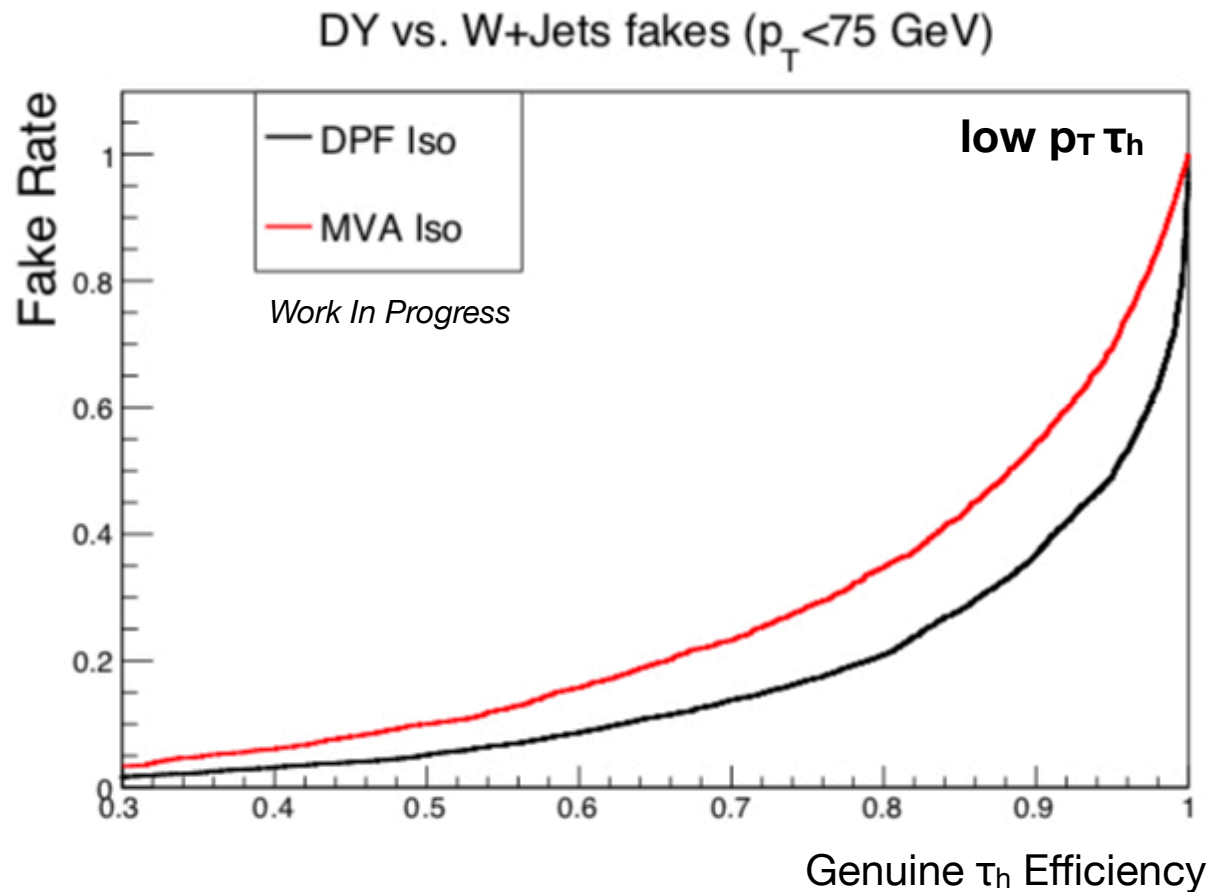
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DeepPF Tau Iso. Performance



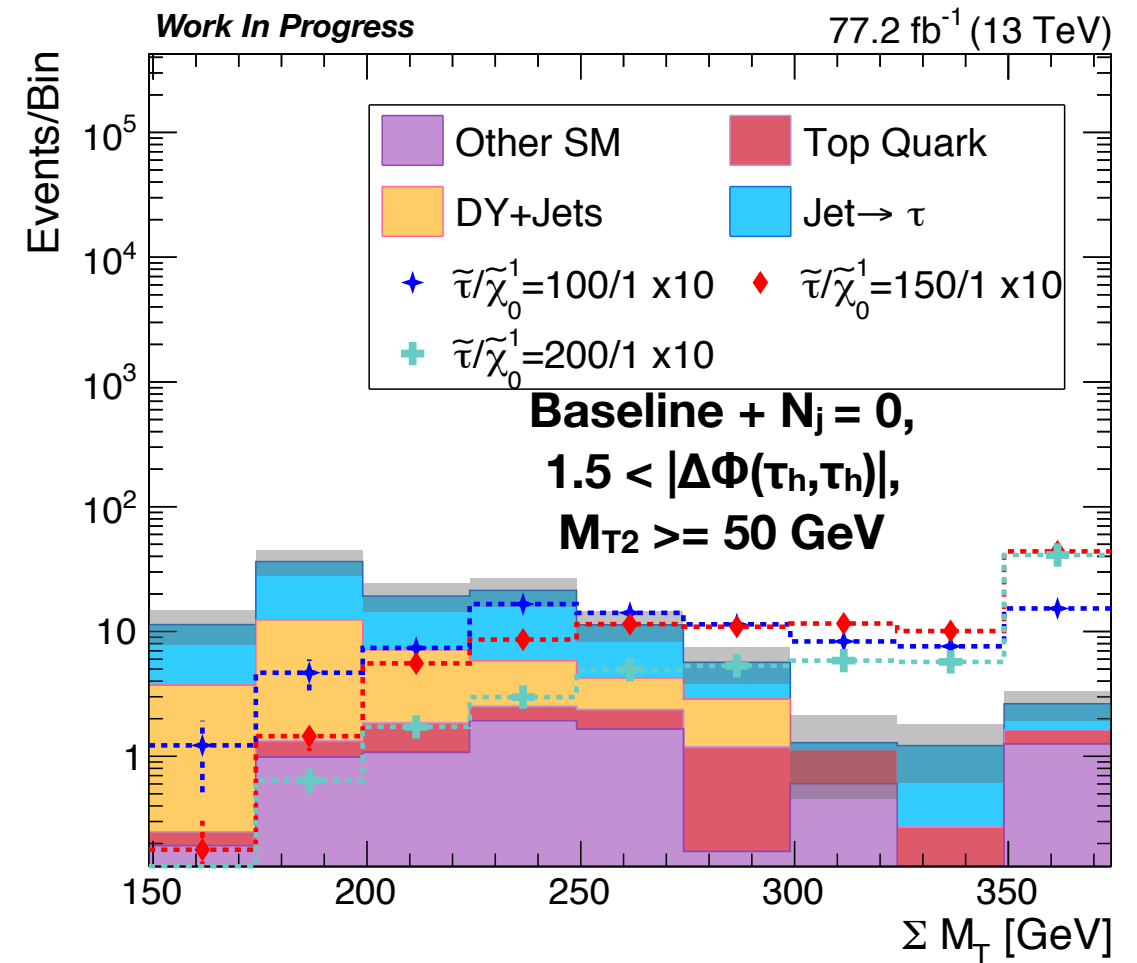
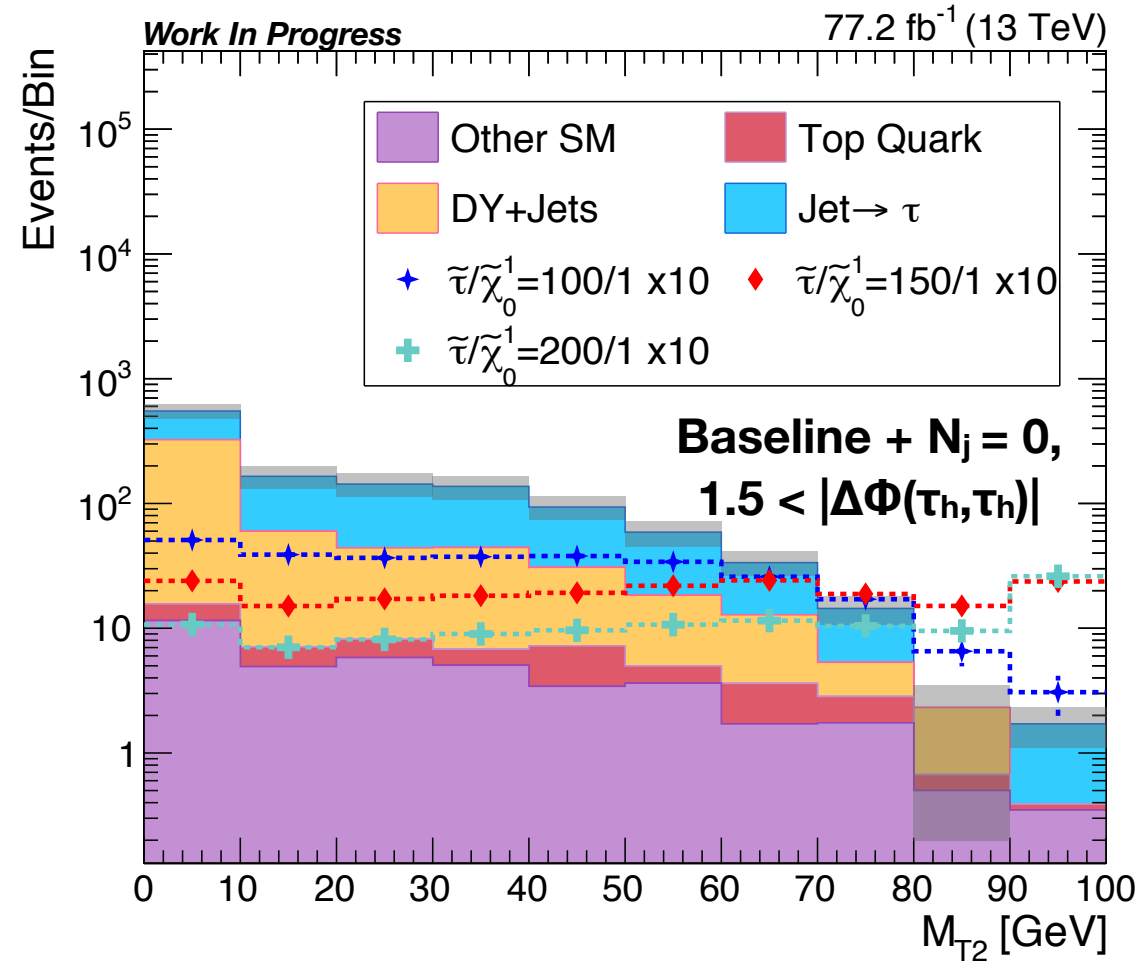
Performance for reco. tau candidates passing analysis selections

- Analysis operates at $\sim 75\%$ efficiency on the curves above
 - **Results in \sim a factor of 2 decrease in tau fake rate w.r.t. previous best multivariate (MVA) approach**
- Performance confirmed in data

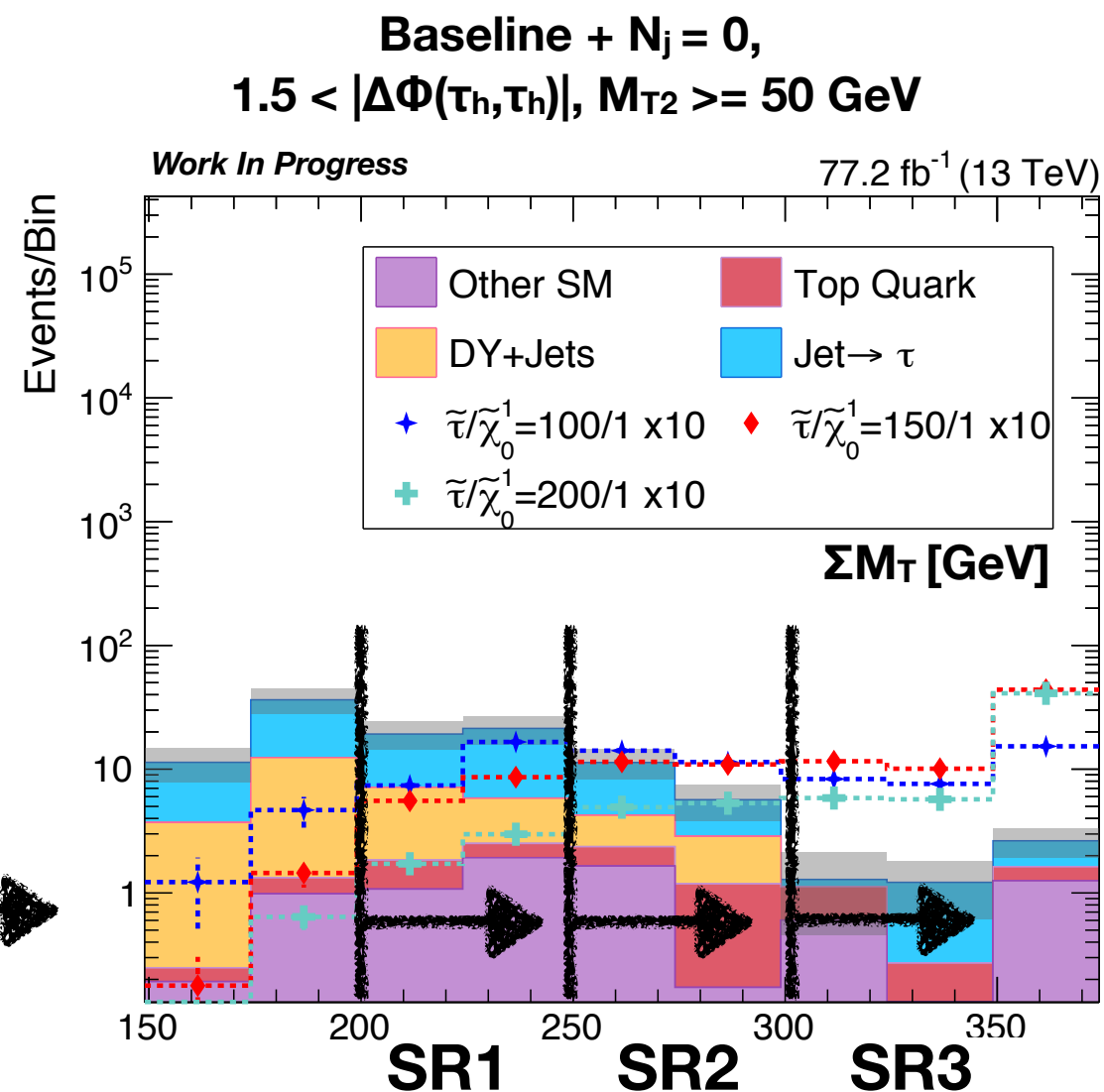
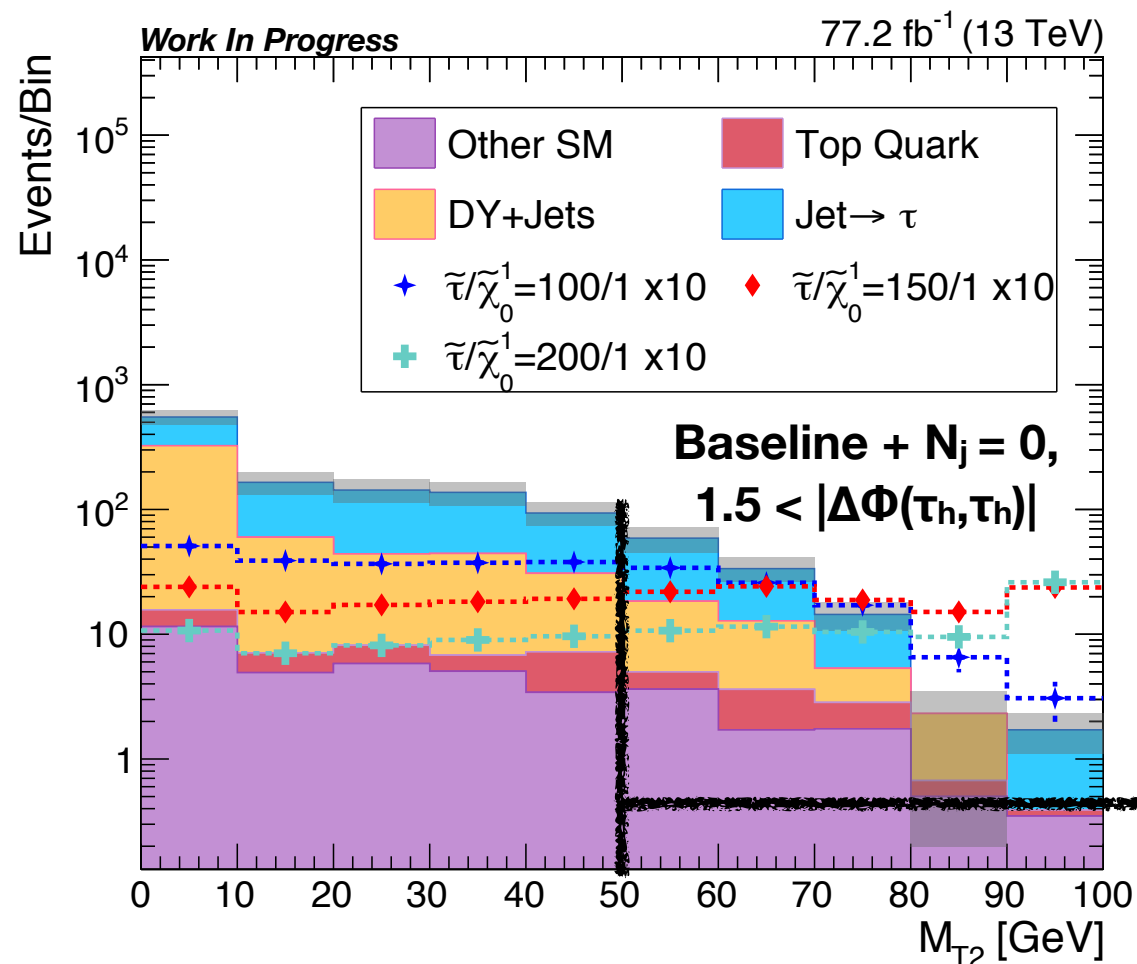
Latest Stau Analysis

Introducing binning in number of reconstructed jets (N_j)

- $N_j = 0$ category enhances signal purity



Latest Stau Analysis



Analysis has been re-designed, more data collected

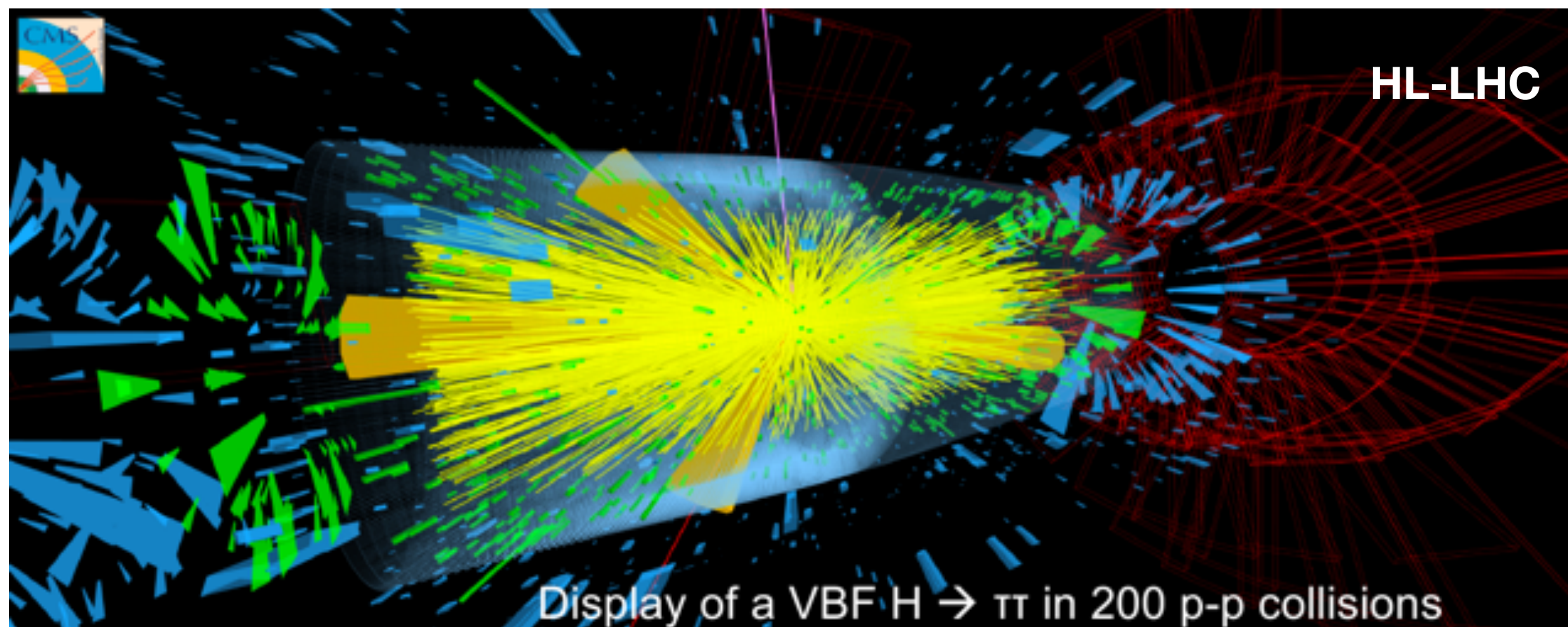
- Binning in N_j and along ΣM_τ brings more sensitivity to a range of masses
- More than double the collected data analyzed
- **Expected to exclude some stau production scenarios with latest analysis reboot**

Future Searches for Staus

Despite the latest improvements, sensitivity to direct stau production at the LHC will always be somewhat limited by the small production cross-section

Future Searches for Staus

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The High-Luminosity LHC (HL-LHC) proposes to collect ~90 times the data analyzed by the first CMS result referenced on S7

➔ **Can we discover stau production at the HL-LHC?**

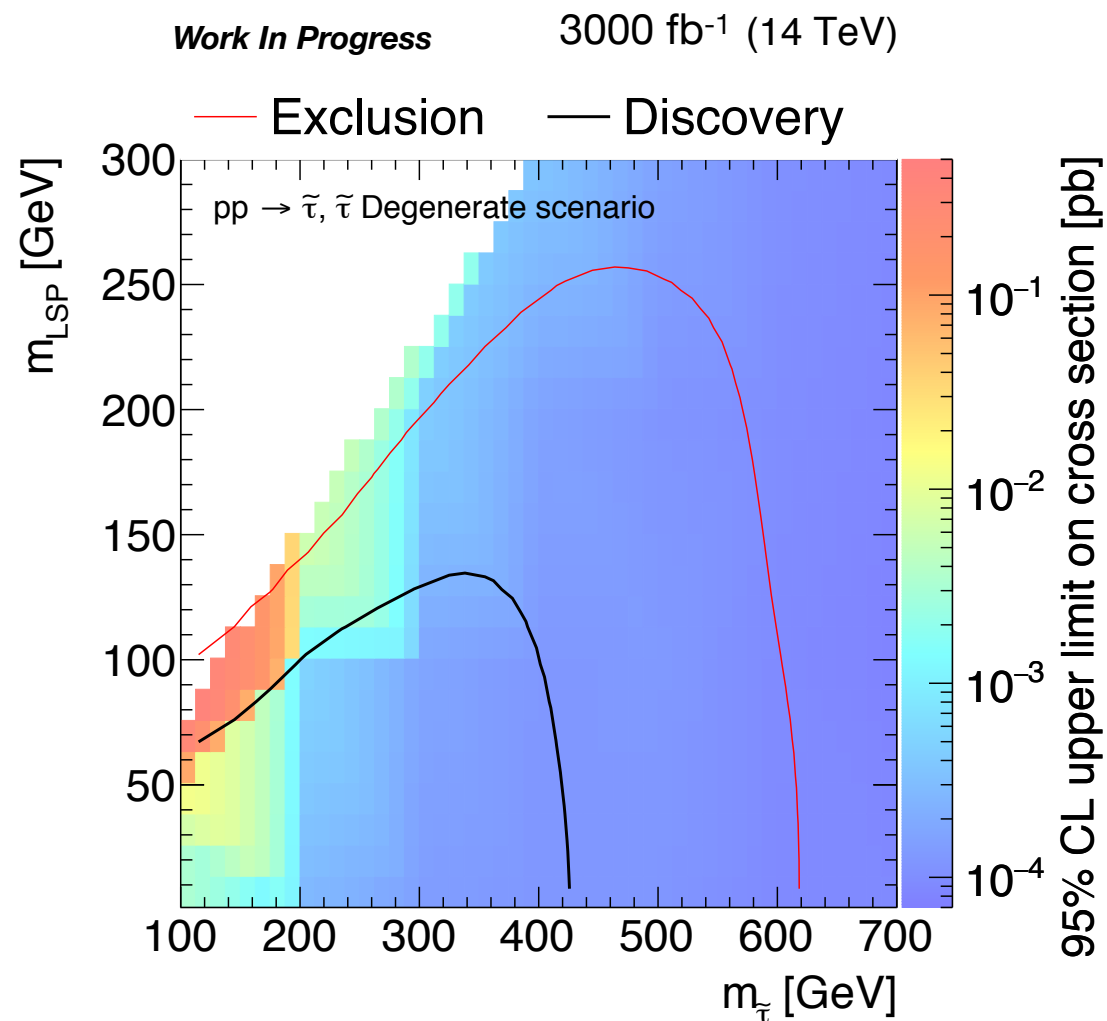
HL-LHC Projections

A new analysis in HL-LHC settings was optimized and carried out :

**$T_h - T_h$
Binning**

Variable	Bin-0	Bin-1	Bin-2	Bin-3
M_{T2}	$50 < M_{T2} < 100 \text{ GeV}$	$100 < M_{T2} < 150 \text{ GeV}$	$150 < M_{T2} < 200 \text{ GeV}$	$M_{T2} > 200 \text{ GeV}$
ΣM_T	$400 < \Sigma M_T < 500 \text{ GeV}$	$500 < \Sigma M_T < 600 \text{ GeV}$	$\Sigma M_T > 600 \text{ GeV}$	
N_j	$= 0$	> 0		

Binning is performed along each var axis, 24 bins in all.

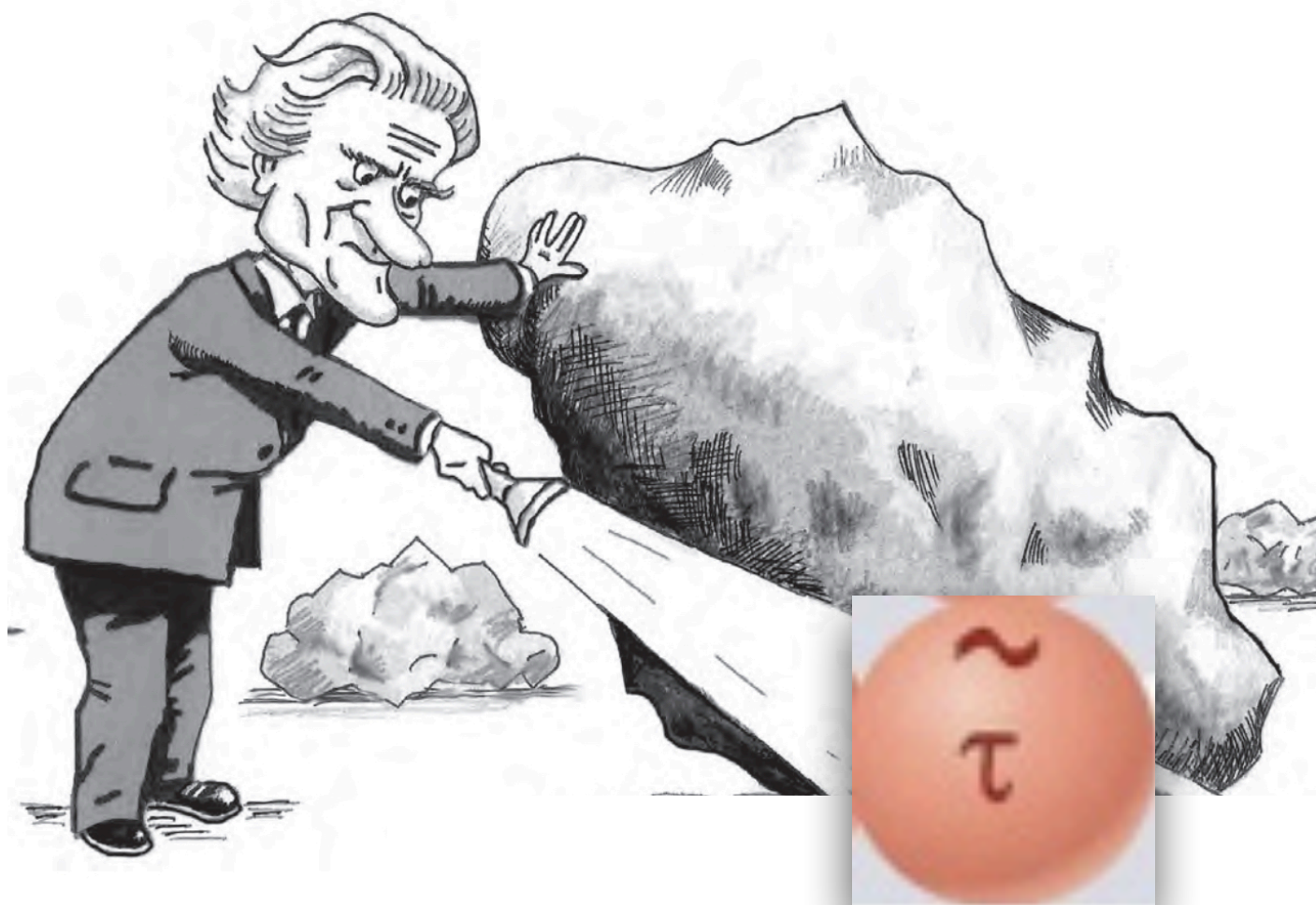


Results are interpreted for optimistic (degenerate) direct stau production :

- Discovery reach to ~400 GeV !

Summary

1. Searching for direct production of stau leptons is well motivated
 - ▶ Leave no stone unturned — Null-results for strongly produced SUSY encourage us to expand our suite of searches



Summary

1. Searching for direct production of stau leptons is well motivated
 - ▶ Leave no stone unturned — Null-results for strongly produced SUSY encourage us to expand our suite of searches
2. Combatting limited sensitivity of the 2016 CMS result
 - ▶ Designed “**DeepPF**” - a **DNN using particle-flow** level inputs to improve performance of tau id. at CMS and push us closer and closer to sensitivity
 - ▶ Latest analysis has been **re-optimized for greater sensitivity.. stay tuned to see if we discover SUSY!**
3. HL-LHC studies show sensitivity for a range of phase space after 3000 fb⁻¹
 - ▶ There is still a long time between now and 2035, it is quite likely that this performance can be exceeded.